

Quantum for education

Adrian Schmidt, KIT-ITAS



Adrian Schmidt

■ Former positions

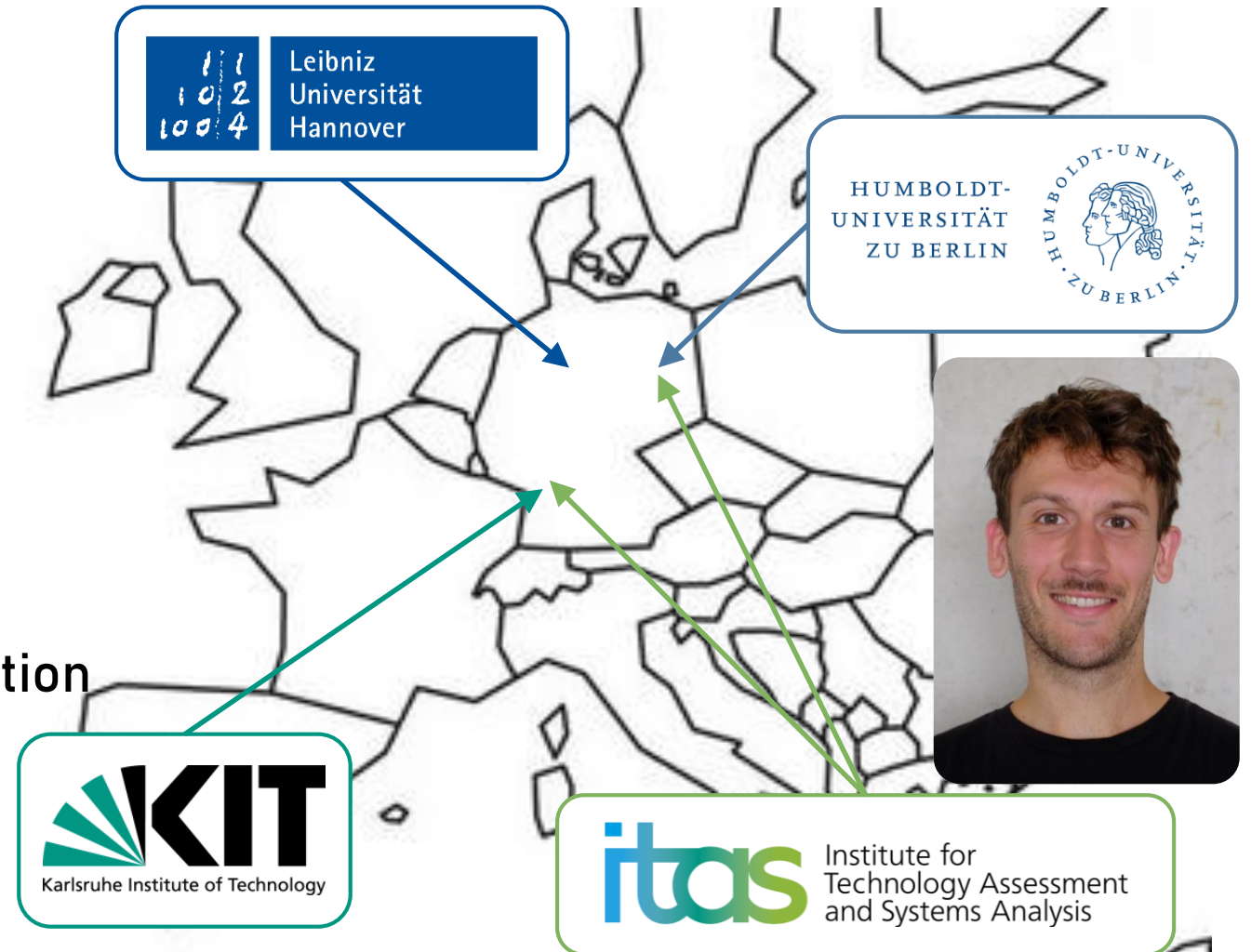
- Physics (Quantum Computing)
- Education Research
- Teacher
- NGO (Space Science)

■ I am not

- Educator
- Quantum Education Researcher
- Knowing everything about QEducation

■ Now

- Technology Assessment (QT)

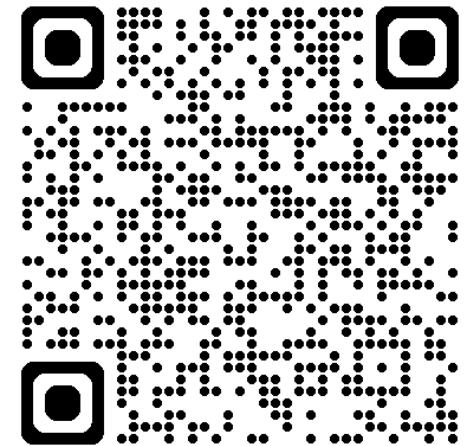




Institute for
Technology Assessment
and Systems Analysis

QuTec: Quantum Technology Innovations for Society

- Research group LIGHT (Cristopher Coenen)
 - Zeki C. Seskir
 - Adrian Schmidt
 - Ulrike Genenz
- Technology assessment of quantum technologies
 - Societal implications of QT
 - Landscape of QT
 - Policy advice
 - Art-science interactions
 - Education and outreach



itas Institute for
Technology Assessment
and Systems Analysis

How do I see my
role?

Potential economic value from quantum computing in 2035

~\$0.9T–\$2T

potential economic value across four industries by 2035: chemicals, life sciences, finance, and mobility¹

Quantum Technology Monitor. (2024). McKinsey Digital.
<https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/steady-progress-in-approaching-the-quantum-advantage/>

“vs”



The Quantum Hype Bubble Is About To Burst

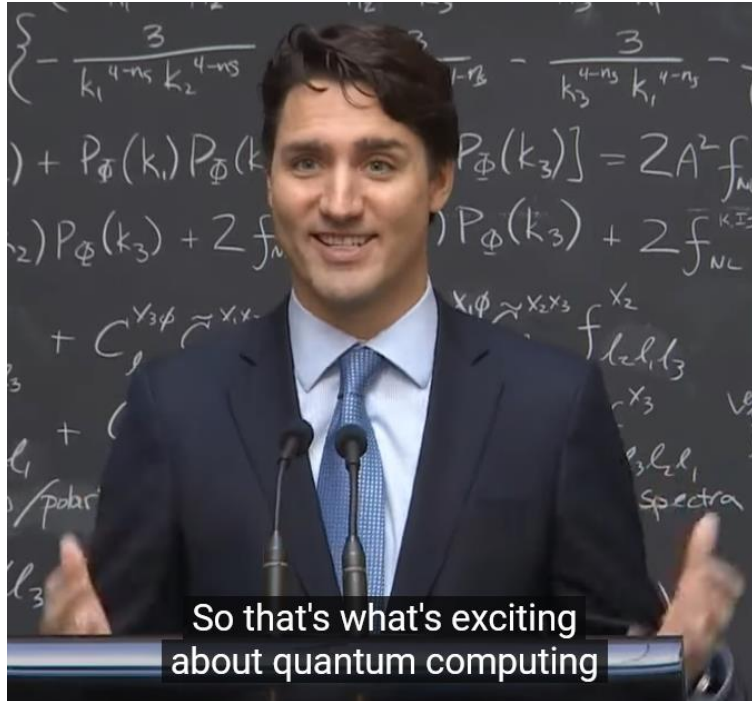
Sabine Hossenfelder ✓
1,5 Mio. Abonnenten

Mitglied werden Abonnieren

35.093 | Teilen

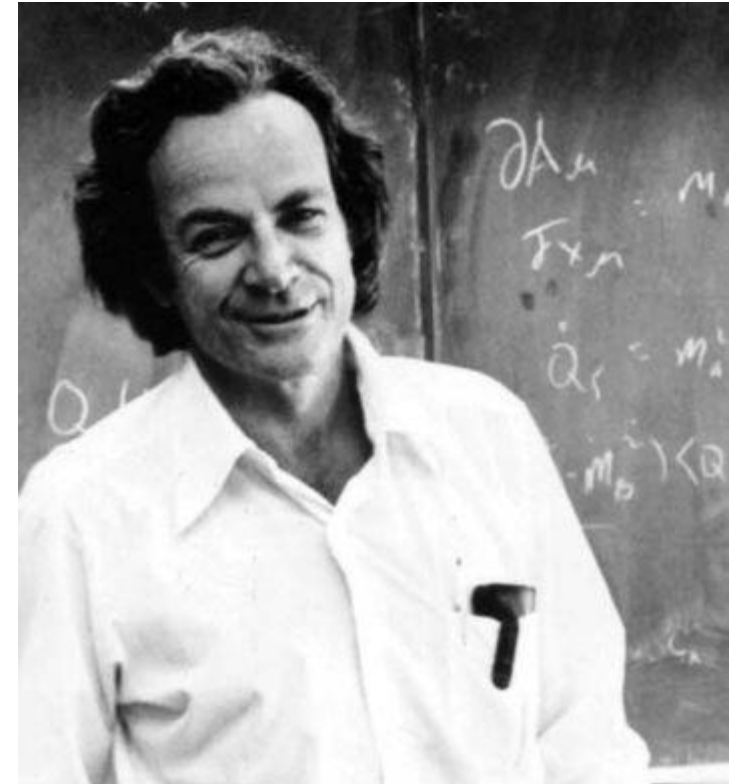
880.028 Aufrufe vor 1 Jahr #quantum #physics #science

<https://www.youtube.com/watch?v=CBLVtCYHVO8&t=1s>



https://www.youtube.com/watch?v=Eak_ogYMprk

“vs”



„[...] I think I can safely say that nobody understands quantum mechanics. [...]”

Give a realistic picture

Raise issues

How do I see my **role?**

Show solutions

Who does work on
**Quantum
Technologies?**

Who thought about
Quantum
Education before?

Why consider Quantum Education?

Workforce shortage
Market needs
Skills

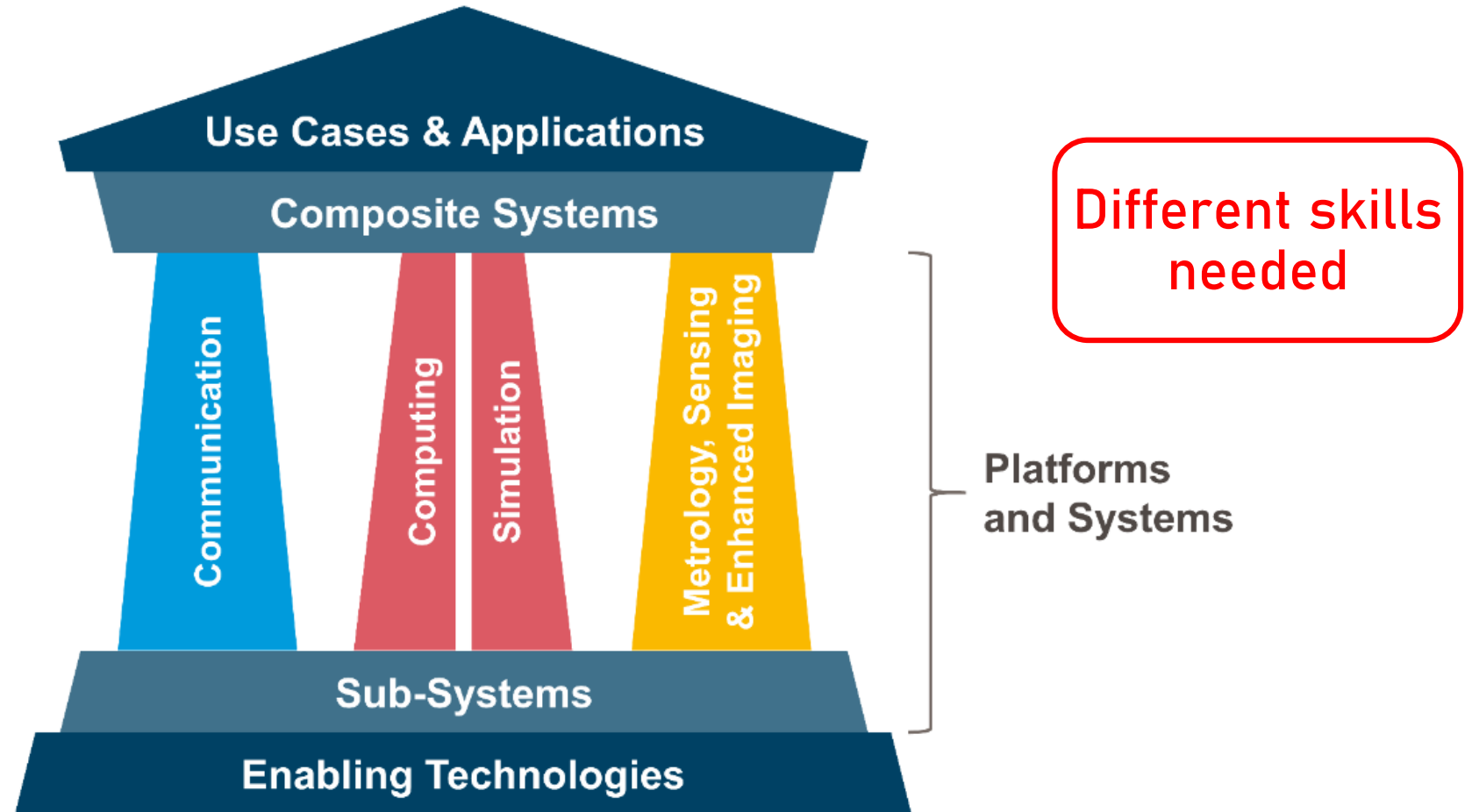
Quantum Divide
Access
Agency

What should be learned, when, from whom, how and why?

What?

Content

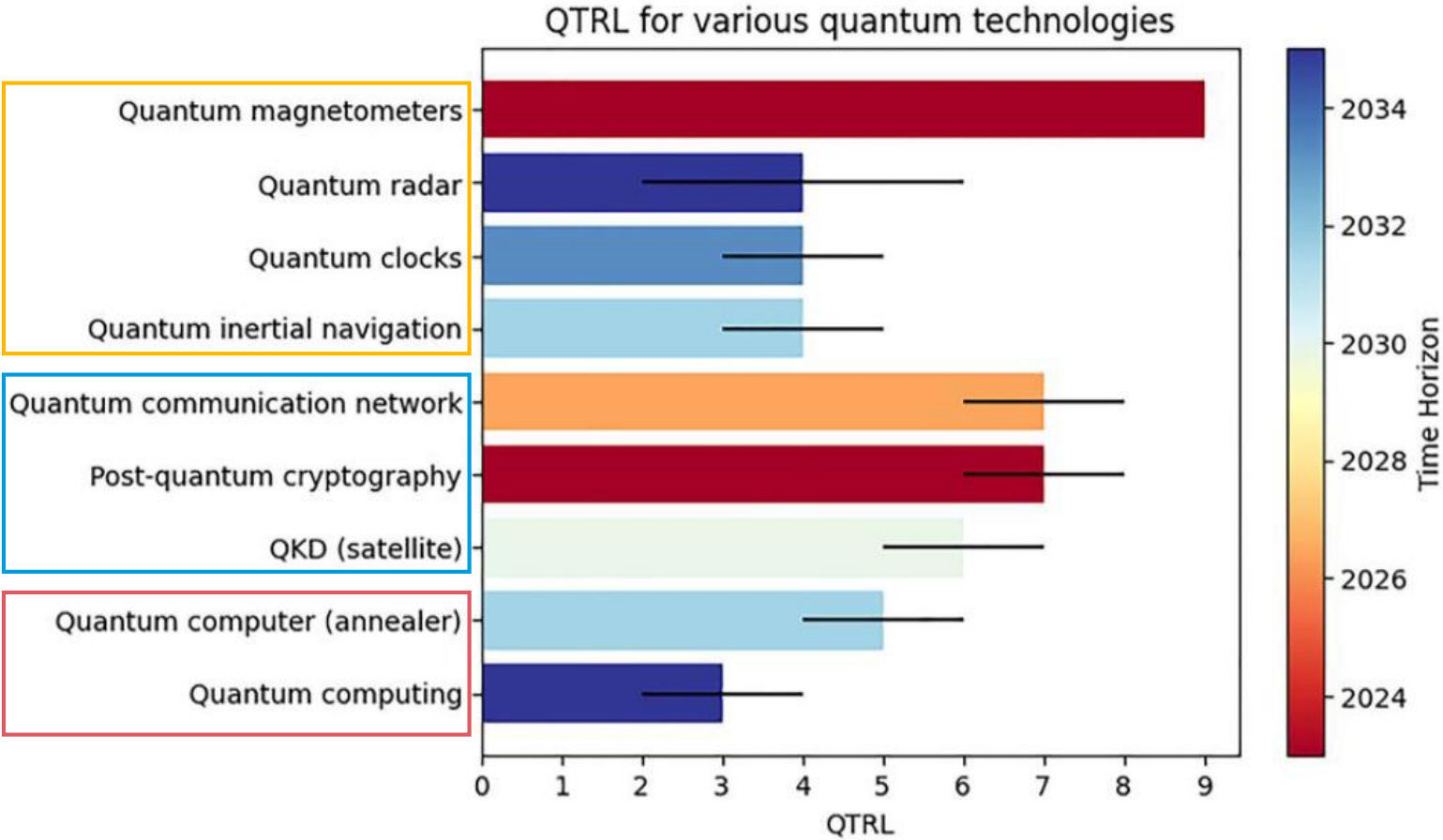
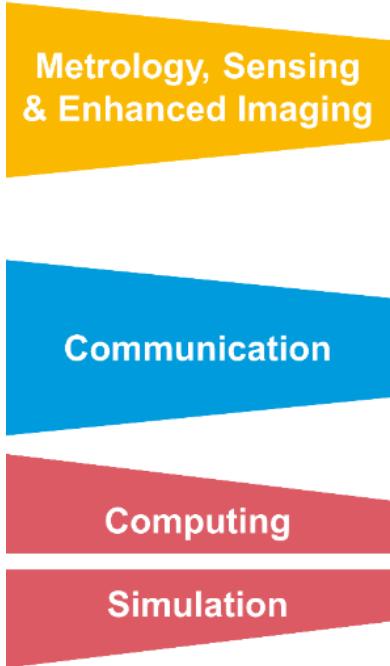
Different Quantum Technologies



CEN-CENELEC FGQT Standardisation Roadmap for Quantum Technologies. Document N020

Different (Quantum) Technology Readiness Levels

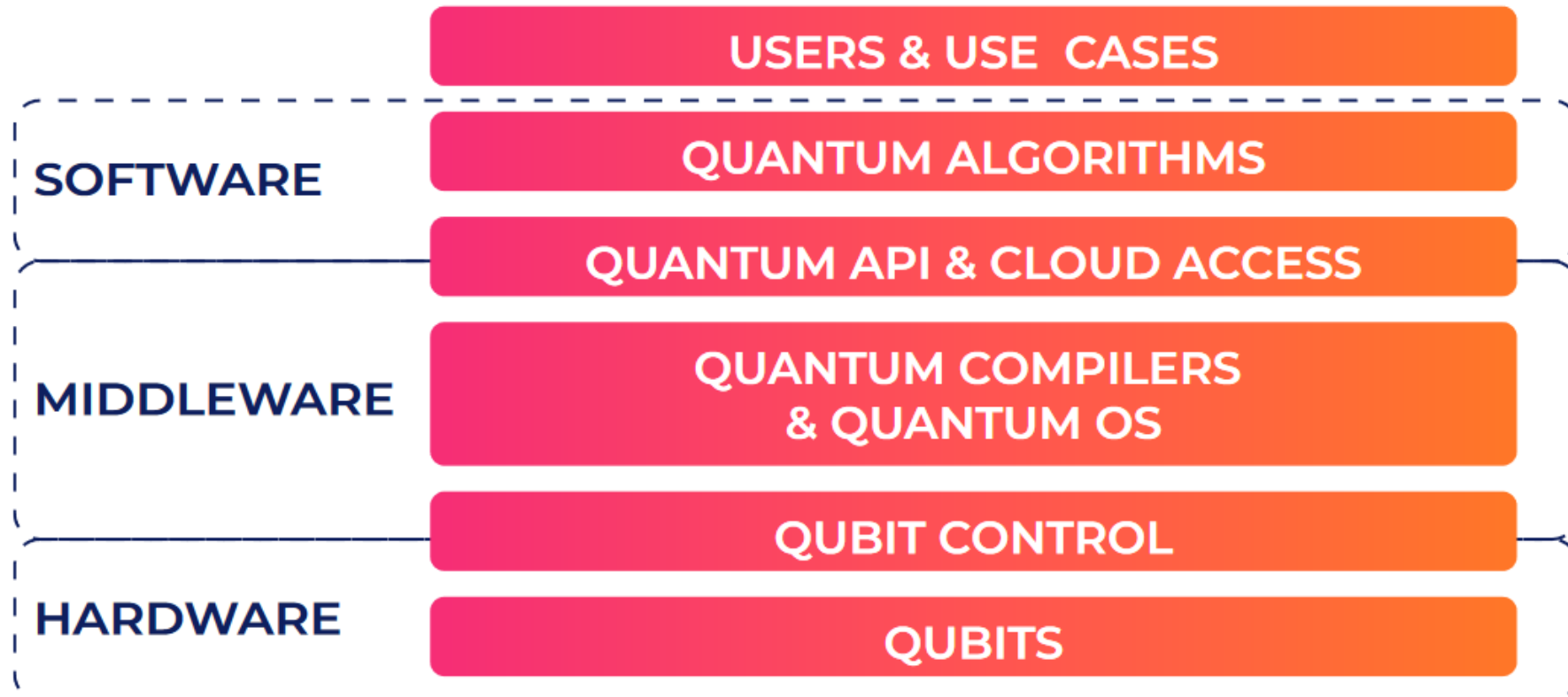
Different timing



Purohit, A., Kaur, M., Seskir, Z. C., Posner, M. T., & Venegas-Gomez, A. (2023). Building a quantum-ready ecosystem. *IET Quantum Communication*, n/a(n/a). <https://doi.org/10.1049/qtc2.12072>

Different jobs within one QT (Quantum Computing)

Different jobs,
skills



Strategic-Research-and-Industry-Agenda-2030.pdf. (n.d.). Retrieved 22 February 2024,
<https://qt.eu/media/pdf/Strategic-Research-and-Industry-Agenda-2030.pdf?m=1707900786&>

Different hardware paths

Leading technologies

Superconducting circuits

- Qubit: excitation of an electronic mode
- Two types: transmons & Fluxmons

aws, IQC, IQM, IBM, Google, rigetti

Trapped ions

- Qubit: 2 internal states of ions
- Long coherence time, high gate fidelity
- Hardly scalable

AQT, aws, IONQ, QUANTINUUM

Neutral atoms (+Rydberg)

- Qubit: excitation of the atoms

aws, QuEra, PASQAL

Colour centers

- Qubit: point defect in crystal
- Very clean
- Difficult to make

QUANTUM BRILLIANCE

Spin qubits / quantum dots

- Qubit: up or down spin of a particle (electron or hole)
- Uses the semiconductor industry

SPIN, IBM, intel, quobly

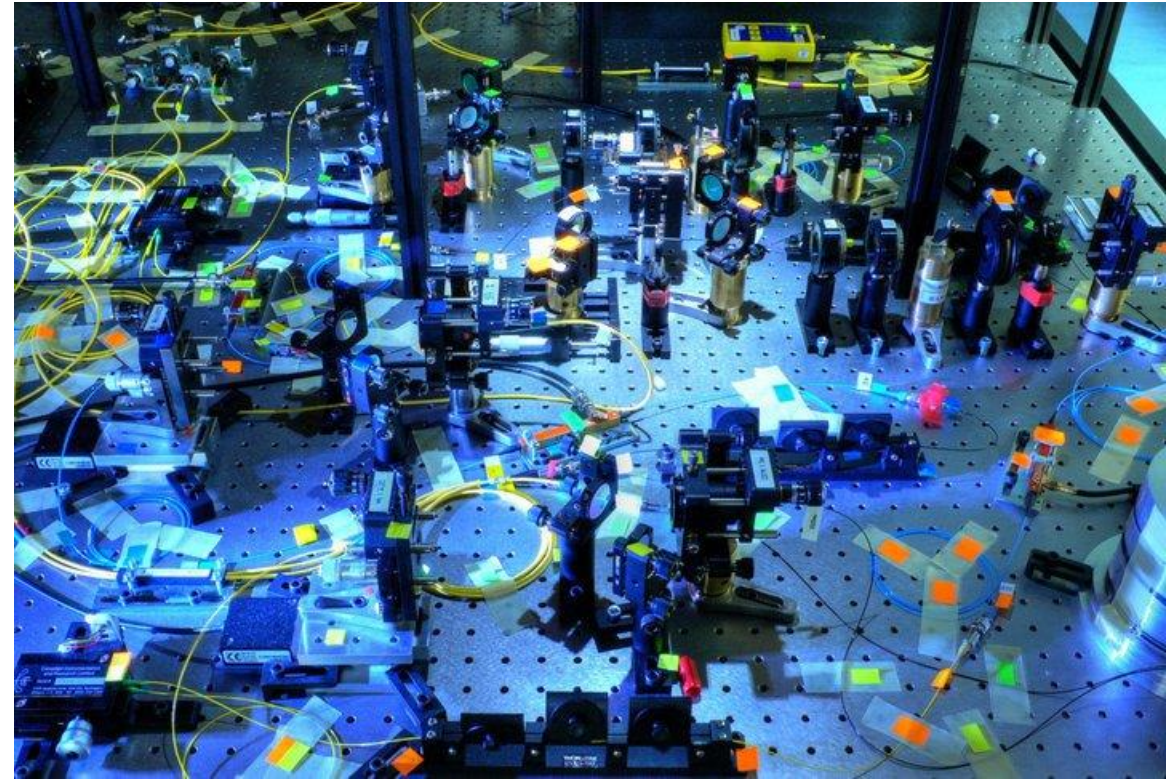
Photons

- Mainly used as information carrier (travel at the speed of light)
- Difficult to make gates

XANADU, ALICE & BOB, PsiQuantum

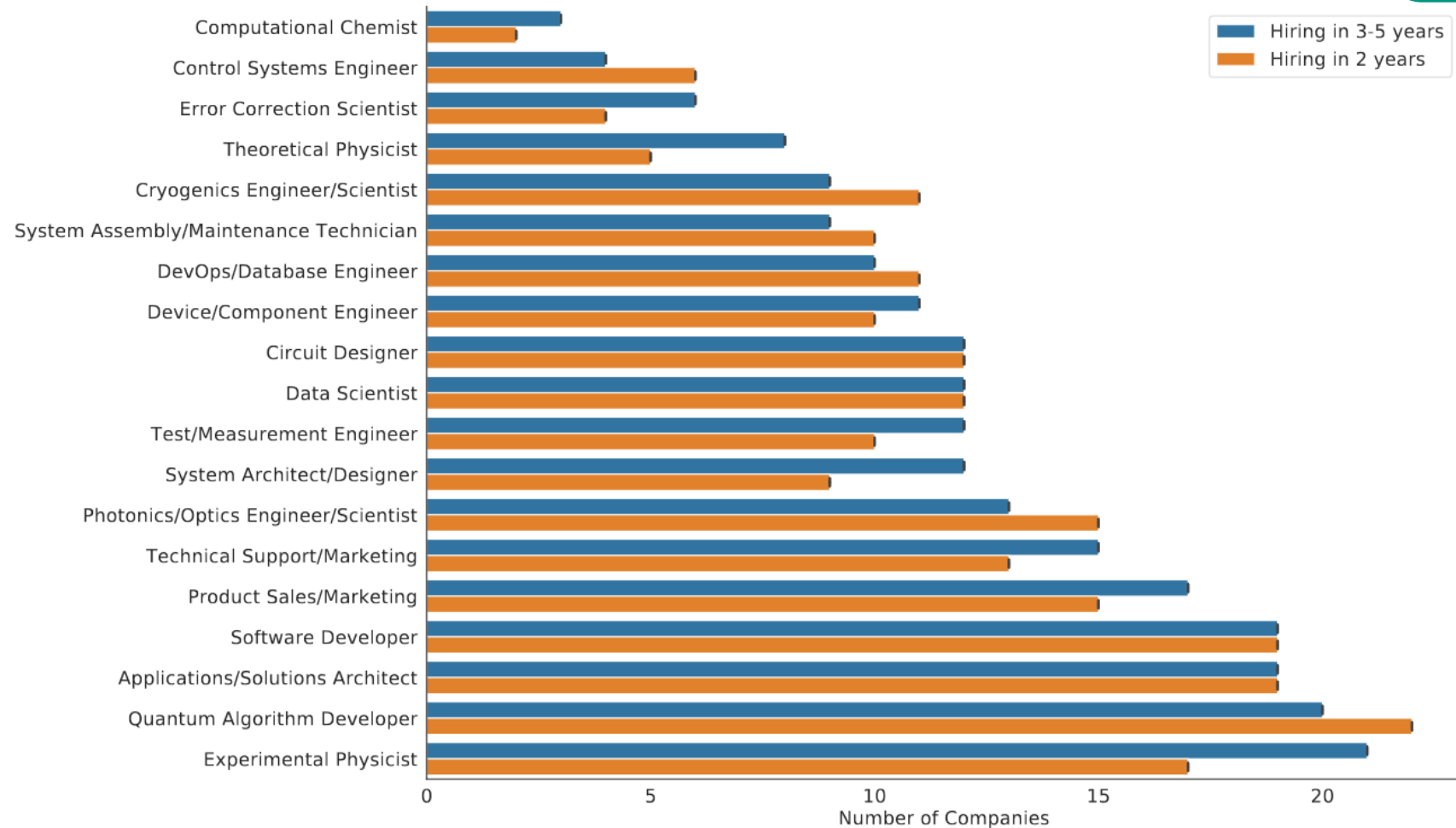
Different hardware paths

Different developments



Needs of the Quantum Industry

Needs identified



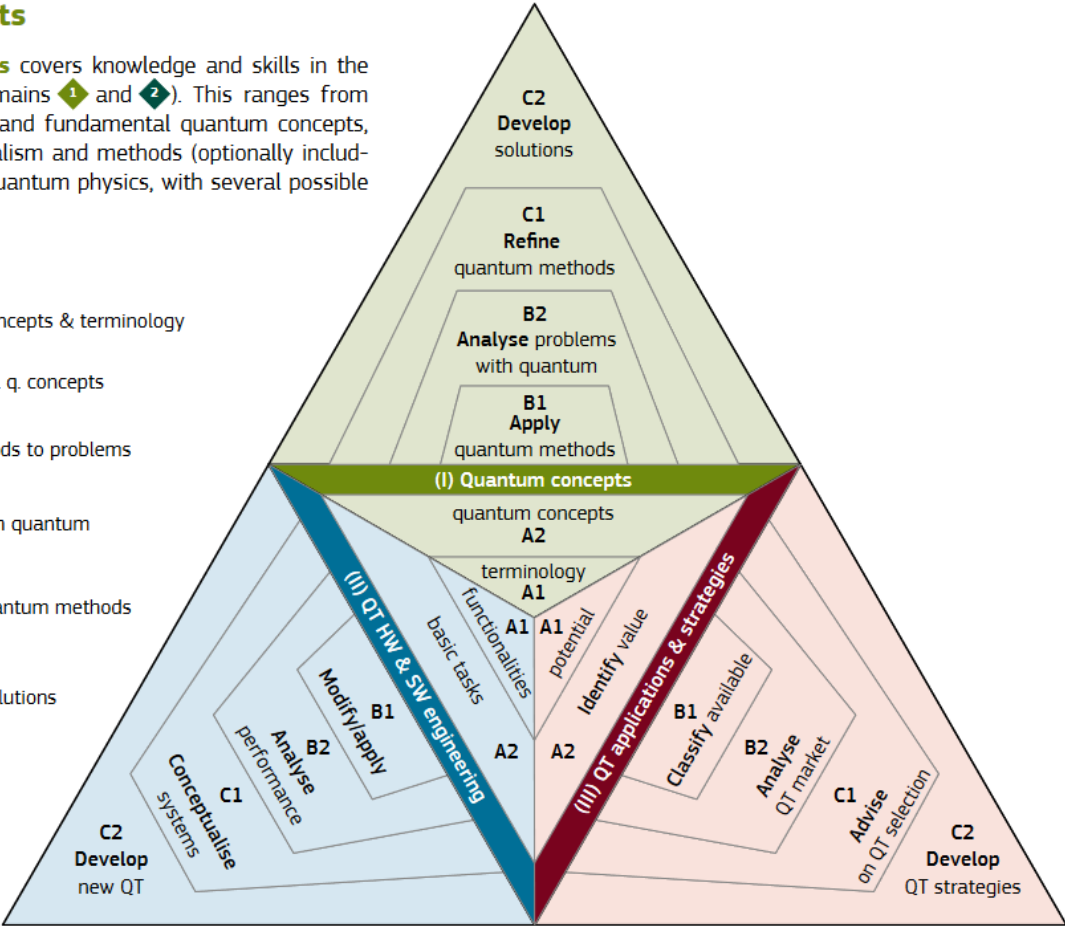
Hughes, C., Finke, D., German, D.-A., Merzbacher, C., Vora, P. M., & Lewandowski, H. J. (2021). *Assessing the Needs of the Quantum Industry* (arXiv:2109.03601).

European Competence Framework for Quantum Technologies

(I) Quantum concepts

Area (I) **Quantum concepts** covers knowledge and skills in the **quantum background** (domains 1 and 2). This ranges from basic quantum terminology and fundamental quantum concepts, through mathematical formalism and methods (optionally including information theory), to quantum physics, with several possible specialisations.

- A1** **A1 Awareness**
Reproduce basic q. concepts & terminology
- A2** **A2 Literacy**
Describe fundamental q. concepts
- B1** **B1 Utilisation**
Apply quantum methods to problems
- B2** **B2 Investigation**
Analyse problems with quantum
- C1** **C1 Specialisation**
Refine and extend quantum methods
- C2** **C2 Innovation**
Develop innovative solutions



Show different paths

No clear consensus yet

Basic skills

Franziska Greinert, Rainer Müller et al., European Competence Framework for Quantum Technologies, from <https://qtedu.eu/european-competence-framework-quantum-technologies>

What?

NOW!

When?

Educational Level

School? University?

both

Growing the Quantum Workforce

Launched by the White House Office of Science and Technology Policy and the National Science Foundation, Q-12 is a consortium that will expand access to K-12 quantum learning tools and inspire the next generation of quantum leaders.

[Learn more](#)

<https://q12education.org/learning-materials-framework>

Full QT master's or single courses?

both

The screenshot shows the top navigation bar of the QTEdu website. The logo on the left is 'QTEdu QUANTUM TECHNOLOGY EDUCATION'. The navigation menu includes 'About', 'News & Events', 'WORK WITH COMMUNITY', 'RESOURCES FOR EVERYONE', and a 'Get involved' button. The main heading is 'Programs, Courses and Trainings' with a sub-heading 'Higher Education' and a brief description of the collection. A 'Submit' button is located at the bottom of the main content area.

This screenshot shows the filter and program details section. On the left, there is a 'FILTERS' section with three buttons: 'PROGRAMS' (highlighted in blue), 'COURSES', and 'TRAININGS'. On the right, a program card is displayed with the following details:

- INTERNSHIP OPPORTUNITY**
- PROGRAM**
- Quantum Technology at RWTH Aachen University**
- COUNTRY: Germany**
- LANGUAGE: English**
- PROVIDER:**

The program description states: 'The program includes an area of specialization in the physics MSc program (in the future it will be offered in the electrical engineering MSc program).'

<https://qtedu.eu/programs-courses-and-trainings/higher-education>

Reskilling & Outreach



<https://qt.eu/projects/archive/csa-projects/qtedu>

What?

When?

How?
Materials

Materials

Collaboration/
Connection

Online courses



Workshops/events



Access, Data



Games



General resources

<https://www.qureca.com/resources/masters-and-phd-opportunities-in-quantum/>

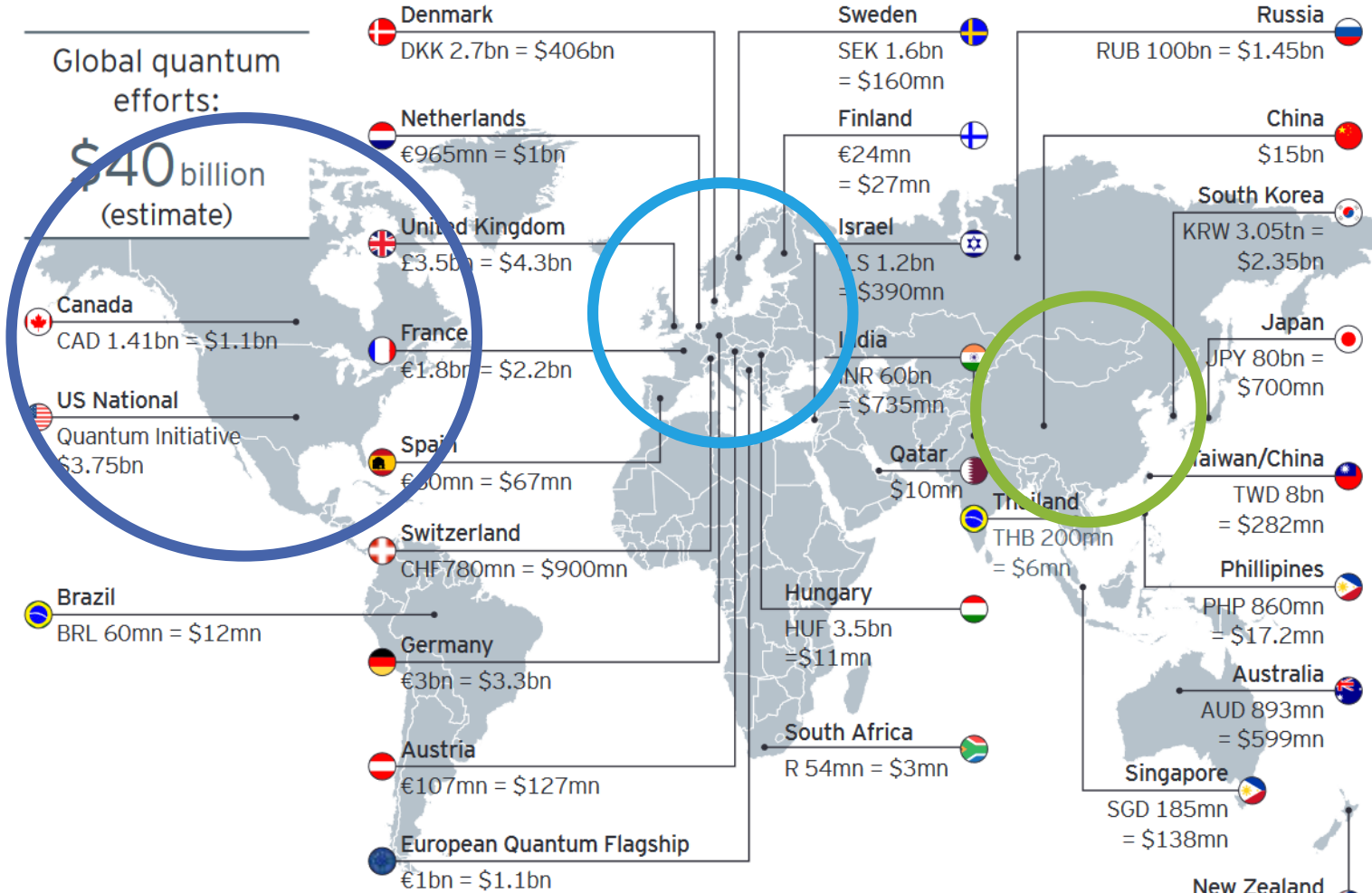
What?

When?

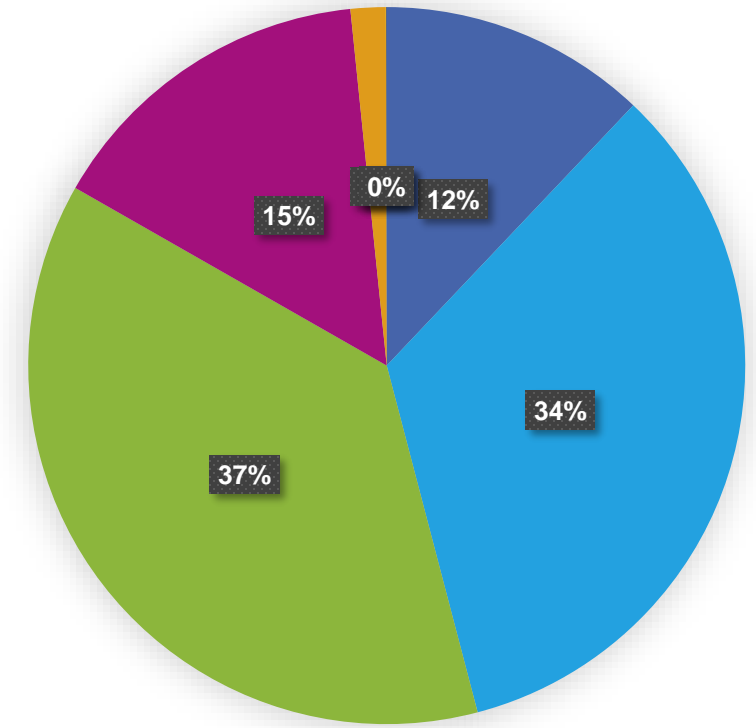
How?

Who?
Audience

Worldwide QT funding (governments)



(Global) Quantum Divide

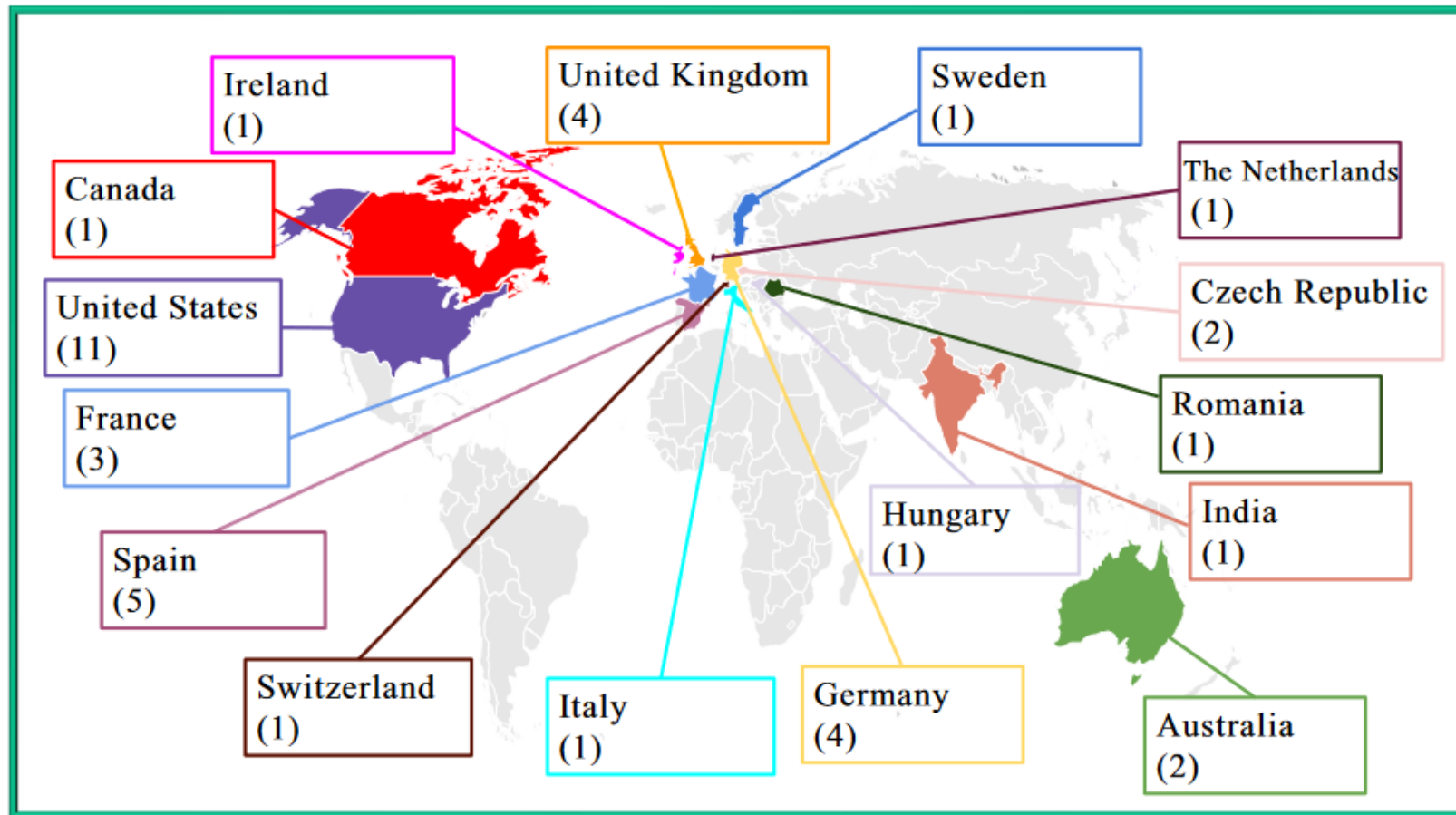


- North America
- Europe
- China
- Asia (without China)
- Oceania
- South America
- Africa

Sources: "Overview of Quantum Initiatives Worldwide 2023". **QURECA**, 19 July 2023; Department of Industry, Science and Resources, Australia, ETH Domain (ETH Zurich, EPFL, PSI).

QT master's programs

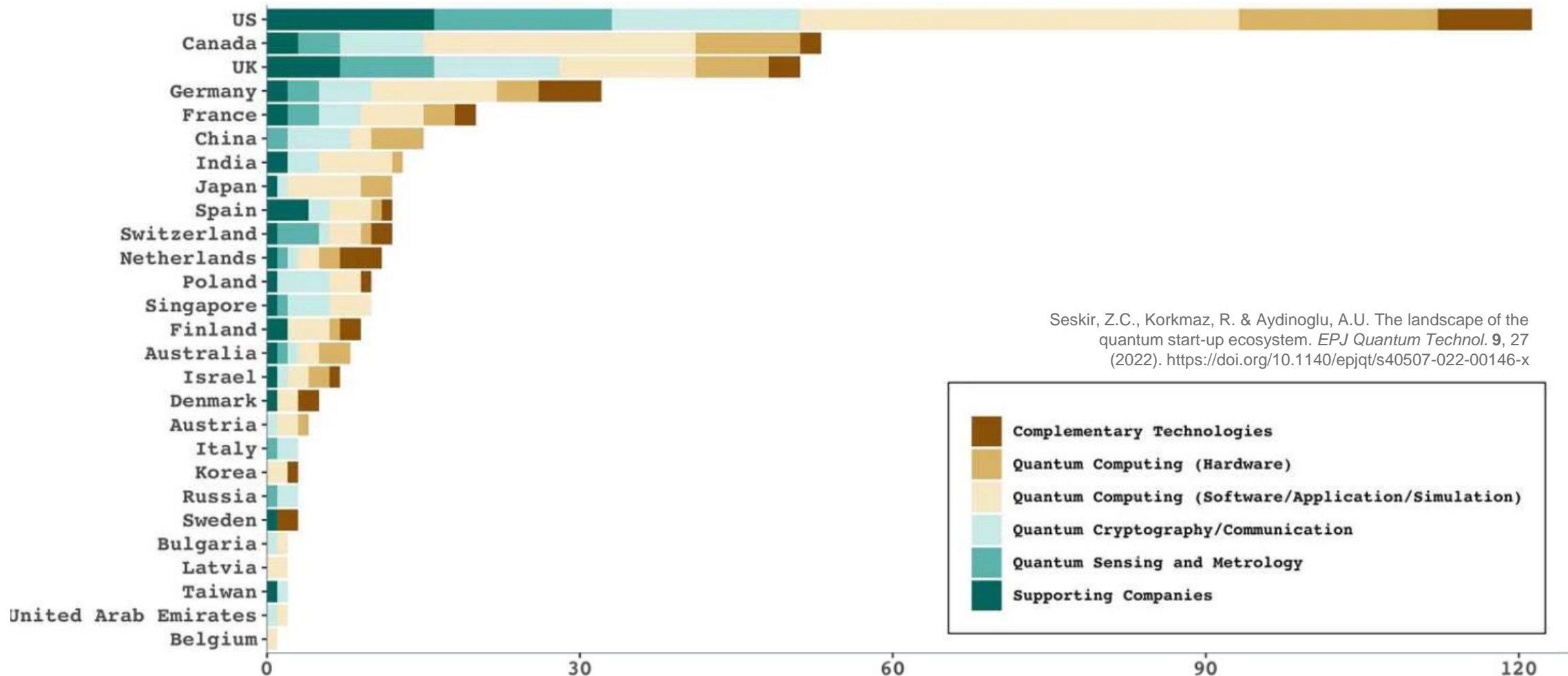
(Global)
Quantum Divide



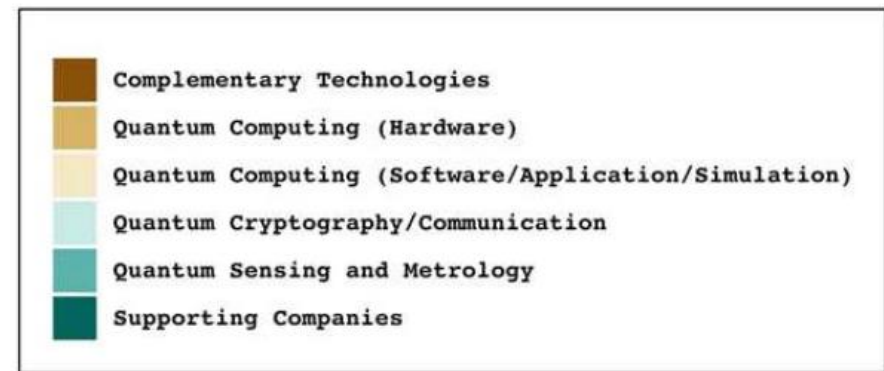
Kaur, M., & Venegas-Gomez, A. (2022). Defining the quantum workforce landscape: a review of global quantum education initiatives. *Optical Engineering*, 61(8), 081806-081806.

QT Startups (2022)

(Global)
Quantum Divide



Seskir, Z.C., Korkmaz, R. & Aydinoglu, A.U. The landscape of the quantum start-up ecosystem. *EPJ Quantum Technol.* **9**, 27 (2022). <https://doi.org/10.1140/epjqt/s40507-022-00146-x>



Access to Quantum Education

(Local)
Quantum Divide

Growing the Quantum Workforce

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[Learn more](#)

Disparities in access to U.S. quantum information education

Josephine C. Meyer^{1,*}, Gina Passante,² and Bethany Wilcox¹

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 (Received 30 November 2023; accepted 25 March 2024; published 2 May 2024)

Driven in large part by the National Quantum Initiative Act of 2018, quantum information science (QIS) coursework and degree programs are rapidly spreading across U.S. institutions. Yet prior work suggests that access to quantum workforce education is unequally distributed, disproportionately benefiting students at private research-focused institutions whose student bodies are unrepresentative of U.S. higher education as a whole. We use regression analysis to analyze the distribution of QIS coursework across 456 institutions of higher learning as of Fall 2022, identifying statistically significant disparities across institutions in particular along the axes of institution classification, funding, and geographic distribution, suggesting today's QIS education programs are largely failing to reach low-income and rural students. We also conduct a brief analysis of the distribution of emerging dedicated QIS degree programs, discovering much the same trends. We conclude with a discussion of implications for educators, policymakers, and education researchers including specific policy recommendations to direct investments in QIS education to schools serving low-income and rural students, leverage existing grassroots diversity and inclusion initiatives that have arisen within the quantum community, and update and modernize procedures for collecting QIS educational data to better track these trends.

DOI: 10.1103/PhysRevPhysEducRes.20.010131

How to bridge the divide

NGOs

[Submitted on 26 Jun 2024 (v1), last revised 14 Jul 2024 (this version, v2)]

Why Teach Quantum In Your Own Time: The Values of Grassroots Organizations Involved in Quantum Technologies Education and Outreach

[Ulrike Genenz](#), [Neelanjana Anne](#), [Zeynep Kılıç](#), [Daniel Mathews](#), [Oya Ok](#), [Adrian Schmidt](#), [Zeki Can Seskir](#)

This paper examines the intersection of goals and values within grassroots organizations operating in the realm of quantum technologies (QT) education. It delineates a fundamental distinction between the objective to provide education and the drive to democratize learning through principles of inclusivity, accessibility, and diversity. The analysis reveals how these organizations navigate their nascent stages, grappling with the dual challenge of adhering to their foundational values while aspiring for sustainable growth and development in the highly specialized field of QT. The study uncovers the strategic approaches adopted by these entities, including efforts to create educational ecosystems and foster community engagement. The research underscores the potential vulnerabilities of these grassroots organizations, particularly in relation to the longevity and evolution of their initiatives as members transition into professional roles within the quantum sector. Through this investigation, the paper contributes to a nuanced understanding of how emerging educational organizations in the QT field balance their ideological commitments with practical growth considerations, highlighting the critical factors that influence their trajectory and impact.

What?

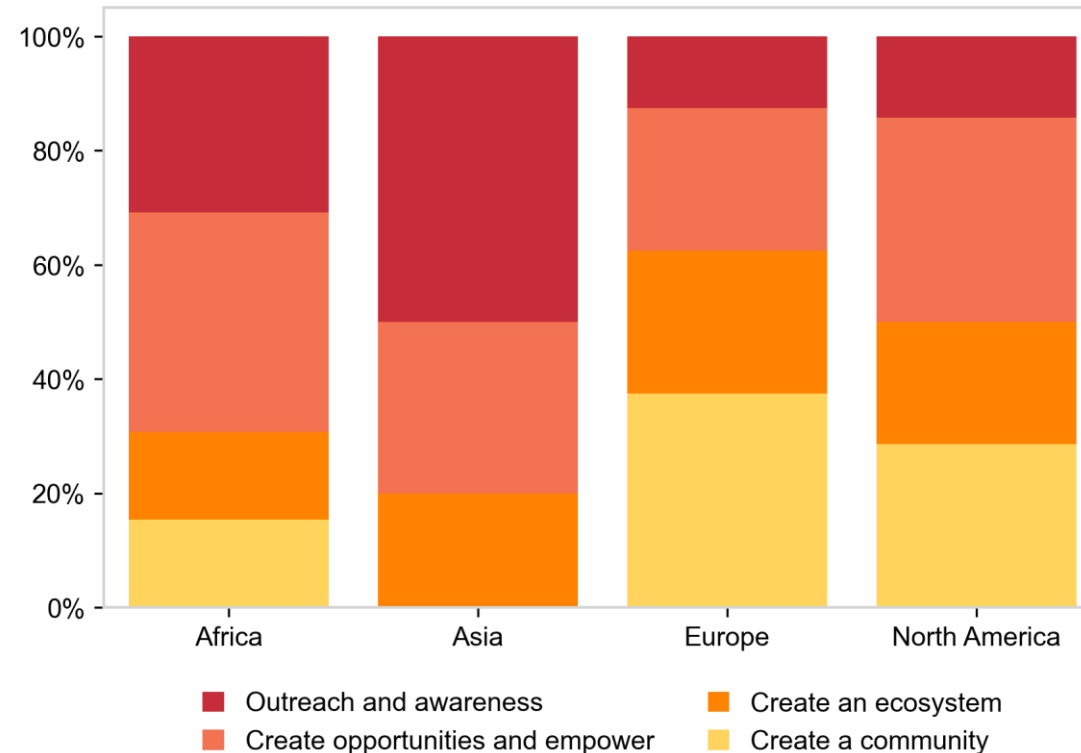
When?

Why?
Motivation

How?

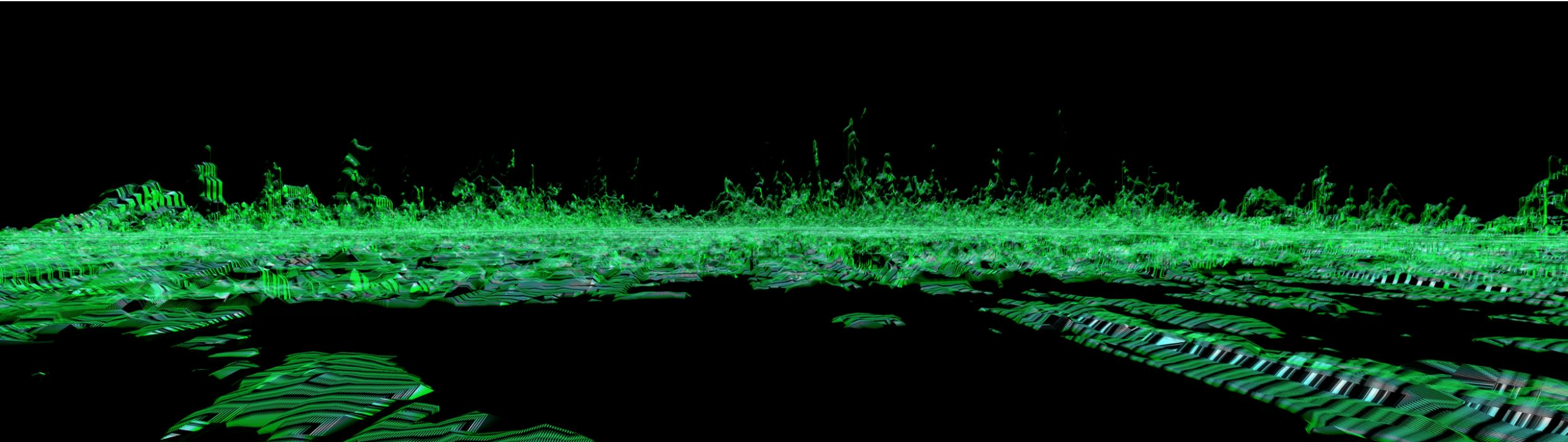
Who?

Motivation of NGO founders (teachers)



Genenz, U., Anne, N., Kılıç, Z., Matthews, D., Ok, O., Schmidt, A., & Seskir, Z. C. (2024). Why Teach Quantum In Your Own Time: The Values of Grassroots Organizations Involved in Quantum Technologies Education and Outreach. *arXiv preprint arXiv:2406.18761*.

Motivation of learners



What?

- Basic QM, programming, laboratory skills
- Be aware of different QTs
- Leave room for development

How?

- Collaboration, sharing ideas and materials
- Use of different materials

Why?

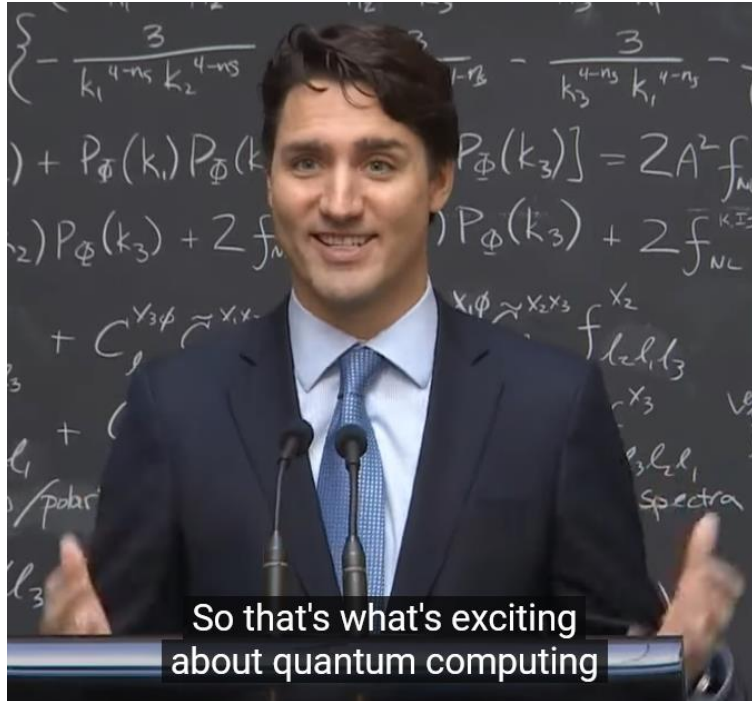
- Different needs for different audiences
- Adapting to motivation of younger generation

When?

- At all levels of education
- QT in various fields of study
- Re-skilling
- General awareness

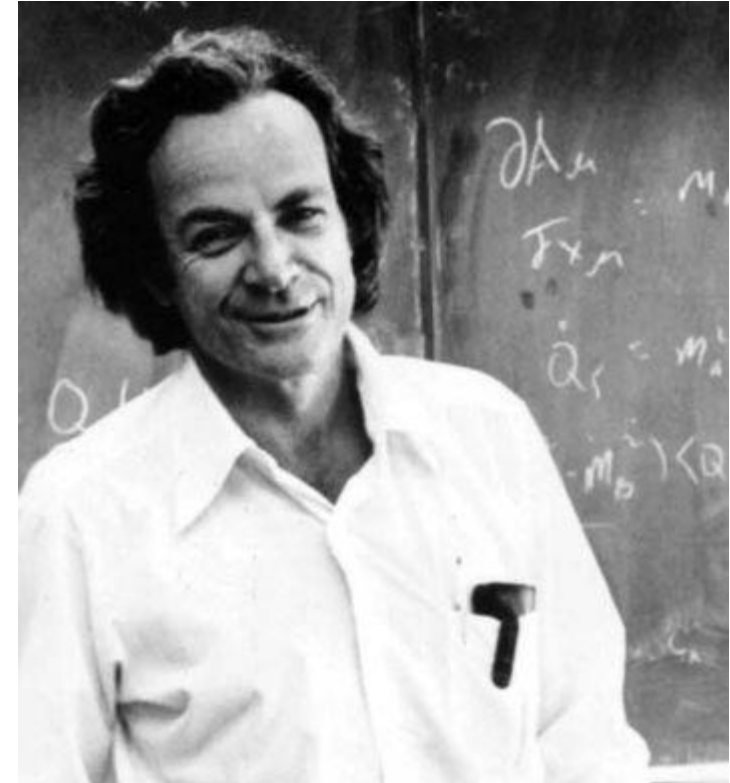
Who?

- Global access to tools needed (QT dependent)
- Awareness,
- Q-12 for all



https://www.youtube.com/watch?v=Eak_ogYMprk

“vs”



„[...] I think I can safely say that nobody understands quantum mechanics. [...]”
in terms of our *common sense notions of reality*

Questions

